

WHAT IS CLAIMED IS:

1. A method for forming a silicon-containing insulation film on a substrate by plasma polymerization, comprising the steps of:

introducing a reaction gas comprising (i) a source gas comprising a silicon-containing hydrocarbon compound containing at least one vinyl group (Si-vinyl compound), and (ii) an additive gas, into a reaction chamber where a substrate is placed; and

applying radio-frequency power to the gas to cause plasma polymerization, thereby depositing an insulation film on the substrate.

2. The method according to Claim 1, wherein the Si-vinyl compound is a compound or compounds selected from the group consisting of linear silicon-containing hydrocarbon compounds having the formula  $\text{Si}_\alpha\text{O}_{\alpha-1}\text{R}_{2\alpha-\beta+2}(\text{OR})_\beta$  wherein  $\alpha$  is an integer of 1-3,  $\beta$  is 0, 1, or 2, R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon, and at least one R attached to Si contains a vinyl group; cyclic compounds having the formula  $\text{Si}_n\text{O}_n\text{R}_{2n}$ , wherein n is an integer of 3-6, R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon, and at least one R attached to Si contains a vinyl group; and cyclic compounds having the formula  $\text{Si}_p(\text{C}_2\text{H}_2)_p\text{R}_{2p}$  wherein p is an integer of 3-6, and R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon.

3. The method according to Claim 2, wherein R is  $-\text{C}_z\text{H}_{2(z-w)+1}$  wherein z is an integer of 2-4, and w represents the number of unsaturated carbon bonds and is an integer of 1-3.

4. The method according to Claim 3, wherein the Si-vinyl compound is a linear compound wherein  $\alpha$  is 1 and  $\beta$  is 0.

5. The method according to Claim 4, wherein the compound is  $(\text{CH}_3)_2\text{Si}(\text{C}_2\text{H}_3)_2$ .

6. The method according to Claim 2, wherein the Si-vinyl compound is a cyclic compound wherein n is 3.

7. The method according to Claim 1, wherein the source gas further comprises a silicon-containing hydrocarbon compound (Si compound) having no vinyl group.

8. The method according to Claim 7, wherein the Si compound is a compound or compounds selected from the group consisting of linear compounds having the formula  $\text{Si}_\alpha\text{O}_{\alpha-1}\text{R}_{2\alpha-\beta+2}(\text{OR})_\beta$  wherein  $\alpha$  is an integer of 1-3,  $\beta$  is 0, 1, or 2, R is  $\text{C}_{1-6}$  saturated

hydrocarbon; and cyclic compounds having the formula  $\text{Si}_n\text{O}_n\text{R}_{2n}$ , wherein  $n$  is an integer of 3-6,  $\text{R}$  is  $\text{C}_{1-6}$  saturated hydrocarbon.

9. The method according to Claim 7, wherein the flow ratio of the Si-vinyl compound to the Si compound is in the range of 10% to 100%.

10. The method according to Claim 1, wherein the additive gas is selected from the group consisting of a carrier gas, an oxidizing gas, and a plasma stabilizing gas.

11. The method according to Claim 10, wherein the plasma stabilizing gas is selected from the group consisting of  $\text{H}_2$ ,  $\text{C}_n\text{H}_{2n+2}$ ,  $\text{C}_n\text{H}_{2n}$ , and  $\text{C}_n\text{H}_{2n+1}\text{OH}$  wherein  $n$  is an integer of 1-5.

12. The method according to Claim 10, wherein the oxidizing gas is selected from the group consisting of  $\text{O}_2$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{O}_3$ , and  $\text{NO}_2$ .

13. The method according to Claim 10, wherein the carrier gas is an inert gas selected from the group consisting of He, Ar, and  $\text{N}_2$ .

14. The method according to Claim 1, wherein the radio-frequency power is high-frequency power.

15. The method according to Claim 14, wherein the high-frequency power has a frequency of 2MHz or higher.

16. The method according to Claim 7, wherein the ratio is controlled to obtain a siloxan polymer having a film stress of 40 MPa or lower and a dielectric constant of 3.0 or lower.

17. The method according to Claim 1, wherein the Si-vinyl compound does not contain Si-O bonds, and the insulation film is a hard film composed of a silicon carbide material.

18. A method for forming a silicon-containing insulation film on a substrate by plasma polymerization, comprising the steps of:

introducing a reaction gas comprising (i) a source gas comprising a silicon-containing hydrocarbon compound containing at least one vinyl group (Si-vinyl compound); (ii) a silicon-containing hydrocarbon compound (Si compound) having no vinyl group; and (iii) an additive gas, into a reaction chamber where a substrate is placed;

controlling the ratio of the Si-vinyl compound to the Si compound in the range of 50% to 100%; and

applying radio-frequency power to the gas to cause plasma polymerization, thereby depositing an insulation film on the substrate.

19. The method according to Claim 18, wherein the Si-vinyl compound is a compound or compounds selected from the group consisting of linear silicon-containing hydrocarbon compounds having the formula  $\text{Si}_\alpha\text{O}_{\alpha-1}\text{R}_{2\alpha-\beta+2}(\text{OR})_\beta$  wherein  $\alpha$  is an integer of 1-3,  $\beta$  is 0, 1, or 2, R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon, and at least one R attached to Si contains a vinyl group; cyclic compounds having the formula  $\text{Si}_n\text{O}_n\text{R}_{2n}$ , wherein n is an integer of 3-6, R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon, and at least one R attached to Si contains a vinyl group; and linear compounds having the formula  $\text{R}-(\text{SiR}_3)_p\text{-H}$  wherein p is an integer of 1-3, and R is  $\text{C}_{1-6}$  saturated or unsaturated hydrocarbon, and at least one R attached to Si contains a vinyl group.

20. The method according to Claim 18, wherein the Si compound is a compound or compounds selected from the group consisting of linear compounds having the formula  $\text{Si}_\alpha\text{O}_{\alpha-1}\text{R}_{2\alpha-\beta+2}(\text{OR})_\beta$  wherein  $\alpha$  is an integer of 1-3,  $\beta$  is 0, 1, or 2, R is  $\text{C}_{1-6}$  saturated hydrocarbon; and cyclic compounds having the formula  $\text{Si}_n\text{O}_n\text{R}_{2n}$ , wherein n is an integer of 3-6, R is  $\text{C}_{1-6}$  saturated hydrocarbon.

21. The method according to Claim 18, wherein the additive gas is selected from the group consisting of a carrier gas, an oxidizing gas, and a plasma stabilizing gas.

22. The method according to Claim 18, wherein the radio-frequency power is high-frequency power.

23. The method according to Claim 18, wherein the ratio is controlled to obtain a siloxan polymer having a film stress of 40 MPa or lower and a dielectric constant of 3.0 or lower.

24. The method according to Claim 17, wherein the Si-vinyl compound and the Si compound do not contain Si-O bonds, and the insulation film is a hard film composed of a silicon carbide material.